The Minas Geofracture

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ABSTRACT

The Minas Geofracture is defined as the east-west boundary between the Meguma and Avalon Zones in and adjacent to Nova Scotia. It is a deep crustal fault that separates dissimilar Precambrian and Lower Paleozoic rocks. It is inferred to have originated during the Middle Devonian Acadian Orogeny. Prior to that time, The Avalon Zone from Boston through coastal Maine and southern New Brunswick to near the Magdalen Islands is interpretated as a southwesterly strike continuation of Cape Breton Island. This palinspastic reconstruction is based upon correlation of Precambrian-Early Devonian lithotectonic and paleogeographic belts. During the Acadian Orogeny a dextral movement of at least 370 to 475 km took place on the Minas Geofracture, followed, in Mid-Late Devonian times, by a dextral movement of at least 280 km upon a fault parallel to Chignecto Bay. Some vertical relief on the Geofracture is indicated by the presence of Mid-Late Devonian molasse only on its northern side. As a consequence of these dextral movements the Magdalen Basin formed as a complex rift where the Appalachians swing through a Z-shaped bend. During Early Carboniferous times the Minas Geofracture was generally inactive: however, initial paleomagnetic results suggest that an internally coherent block, including the Avalon and Meguma Zones, moved 1500 to 2000 km northwards relative to cratonic North America. During the Late Westphalian to Permian Hercynian Orogeny, a dextral movement of approximately 165 km is inferred to have taken place on the Minas Geofracture and a dextral movement of some 95 km along Chignecto Bay. Finally, during Early Mesozoic times, a sinistral movement of approximately 75 km took place on the Minas Geofracture as the Bay of Fundy Rift formed in response to the opening of the Atlantic Ocean.

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RÉSUMÉ

La géofracture de Minas est par définition la limite de direction est-ouest qui sépare les zones d'Avalon et de Méguma en Nouvelle-Ecosse et le secteur limitrophe. C'est une faille crustale profonde jouxtant des roches différentes rattachées au Précambrien et au Paléozoïque inférieur, respectivement. Elle est apparue au cours de l'orogénèse acadienne au Dévonien moyen. Auparavant, la zone d'Avalon depuis Boston en incluant la côte du Maine, le sud du Nouveau-Brunswick et jusqu'au voisinage des Iles-de-la-Madeleine constituait l'extension sud-ouest de l'Ile-du-Cap-Breton. Cette reconstitution palinspatique s'appuie sur une corrélation de zones lithotectoniques et paléogéographiques allant du Précambrien au Dévonien inférieur. Au cours de l'orogénèse acadienne, la géofracture de Minas a subi un mouvement dextre d'au moins 370 à 475 km, suivi au Dévonien supérieur moyen, par un déplacement dextre d'au moins 280 km le long d'une faille parallele à la Baie de Chignecto. Une molasse du Dévonien supérieur moyen indique que le côté nord seulement de la géofracture manifestait un certain relief. De ces mouvements dextres est résulté le bassin des Iles-de-la-Madeleine formant un complexe de rift au lieu où les Appalaches s'incurvent en forme de Z. Au cours du Carbonifère inférieur, la géofracture de Minas est demeurée à peu près inactive; toutefois les premiers résultats d'une étude paléomagnétique suggèrent qu'un bloc cohérent englobant les zones d'Avalon et de Méguma s'est déplacé de 1500 à 2000 km vers le nord relativement au craton nord-américain. Au cours de l'orogénèse hercynienne allant du Westphalien supérieur au Permien, un mouvement dextre d'environ 165 km s'est manifesté le long de la géofracture de Minas en même temps qu'un déplacement dextre de 95 km se produisait à la Baie de Chignecto. Finalement, au Mésozoïque inférieur, un mouvement sénestre d'environ 75 km se produisait à la géofracture de Minas au moment de la création du rift de la Baie de Fundy reliée à l'ouverture de l'Océan Atlantique.

INTRODUCTION

The northern Appalachians have been divided into five zones by Williams (1979). From west to east, these are the Humber, Dunnage, Gander, Avalon and Meguma Zones. The Humber Zone represented during the Late Precambrian-Early Paleozoic, the ancient continental margin of eastern North America; the Dunnage Zone contains the vestiges of Iapetus; the Gander Zone records the development and destruction of a continental margin; the Avalon Zone was an epi-cratonic platform built upon a micro-continent and the Meguma Zone represented either a continental rise or an intra-cratonic trough on the southern margin of the Avalon Zone. Within this context, it is remarkable to find that all of these zones swing through a Z-shaped bend in the Quebec Reentrant (Williams, 1978). In the Humber Zone, this is attributed to the original curvature in the North American craton bordering Iapetus (Williams, 1979). However, it seems fortuitous that the eastern border of Iapetus should exactly parallel the western margin. In this connection, the significance of the major fault running from the Minas Basin into Chedabucto Bay, here named the Minas Geofracture (Fig. 1) is pertinent because it cuts obliquely across the general northeasterly trend of the Appalachians. It is the thesis of this paper that the Avalon and Meguma Zones were originally straight in this area and have been offset in the Quebec Reentrant along the Minas Geofracture.

DEFINITIONS

The Minas Geofracture is a term introduced here and defined as the east-west boundary between the Meguma and Avalon Zones in and adjacent to Nova Scotia (Fig. 1). As such, it is a deep crustal fault or megashear that separates dissimilar Precambrian and Cambro-Ordovician rocks. Although the Precambrian basement beneath the Meguma Zone is not exposed, its seismic compressional wave velocity of 5.4 km/sec on top of 6.25 km/sec contrasts with the 5.7 to 6.3 km/sec on top of 7.4 km/sec recorded in the Avalon Zone (Dainty *et al.*, 1966) exposed as gneiss, metasediments and metavolcanic rocks. The Cambro-Ordovician turbidites of the Meguma Group are distinctly different from the shelf deposits of the Avalon Zone. Nowhere along the Minas Geofracture can Precambrain or Early Paleozoic rocks be observed in contact because a system of faults parallel to the Minas Geofracture downthrows younger rocks between them. The surface projection of the Minas Geofracture runs from the Minas Basin to Chedabucto Bay. Its eastward continuation may be defined by the southern margin of the Collector Magnetic Anomaly (Haworth and Lefort, 1979). It should be noted that this definition of the Minas Geofracture differs from that of the Glooscap Fault System (King *et al.*, 1975). Thus, although the Glooscap Fault System follows the Minas Geofracture through Nova Scotia it departs from it at both ends where the former follows the Fundian Fault System in the west and the Newfoundland Fracture Zone in the east.

Faults parallel to the Minas Geofracture include the Cobequid Fault, Parrsboro Fault, Economy Fault, Riversdale Fault, North River Fault, Watervale Fault, West River St. Mary's Fault, Chedabucto Fault, Guysborough County Fault, and Guys-

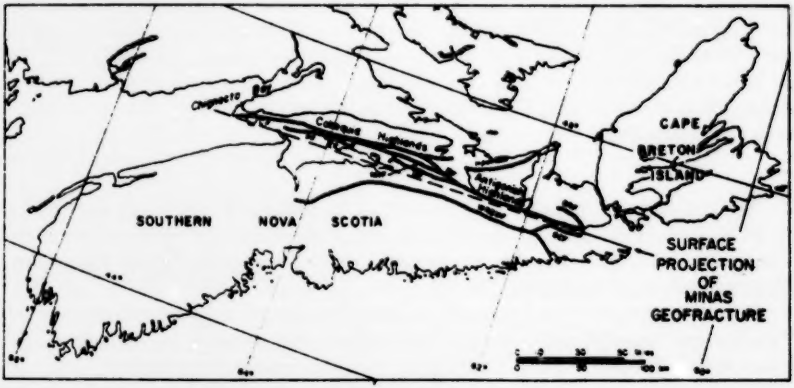

Figure 1. Map of Nova Scotia showing the main east-west faults.
CF = Cobequid Fault, CHF = Chedabucto Fault,
EF = Economy Fault, GCF = Guysborough County Fault,
GRF = Guysborough River Fault, HF = Hollow Fault
NRF = North River Fault, PF = Parrsboro Fault,
RF = Riversdale Fault, WF = Watervale Fault,
WRSMF = West River St. Mary's Fault.

borough River Fault. This has led to the use of the collective terms such as the Cobequid-Chedabucto Fault Zone or System (Webb, 1969) and the Cobequid-Chedabucto-Scatarie Fault System (Lefort and Haworth, 1978). Of all these faults, the Guysborough County Fault most closely approximates the surface projection of the deep crustal Minas Geofracture and all the other faults are merely sub-parallel subsidiaries. It is suggested that the collective term, Minas Fault System, replace the other more cumbersome terms. Movements on the Guysborough County Fault have intensely sheared rocks of the Meguma Group and granitoid plutons many of which exhibit horizontal slickensides. Movements along other individual faults have been variously interpreted to be dextral, sinistral, normal and reverse (Eisbacher, 1969; Benson, 1967, 1974). As such, individual movements probably record only a portion of the complex movement history of the Minas Geofracture.

PALINSPASTIC RECONSTRUCTIONS

Palinspastic reconstructions across major fault zones require the recognition of the same geological features on both sides of the fault. This is possible for faults crossing the Appalachian trend, such as the Minas Geofracture, but is often impossible for strike faults. Reconstructions across the Minas Geofracture can only be made with any degree of certainty for Late Hadrynian and Middle Devonian times using lithotectonic and metamorphic boundaries. Reconstructions for other times are more tentative because they are based upon palaeogeographic lines. Apparent offsets of such lines may be due to either fault displacement or palaeotopographic relief on the fault. For instance, as will be shown later, palaeotopographic relief of the Minas Geofracture Zone is probably the main factor in controlling the distribution of the Late Devonian – Early Carboniferous Horton Group. This renders Webb's (1969) latest Devonian palinspastic map invalid. The palinspastic maps presented here are not strictly palinspastic because they make no adjustments for folding or internal strain, and fault movements are summed on the Minas Geofracture and a fault parallel to Chignecto Bay.

Late Hadrynian

The Precambrian rocks of the Avalon Zone in northern Nova Scotia and southern New Brunswick may be subdivided into four northeast-southwest trending lithotectonic subzones (Fig. 2), all showing varying degrees of Late Hadrynian polyphase deformation (Keppie, 1979c).

The Cape Breton Island subzone is characterized by a gneissic basement of unknown age unconformably overlain by miogeoclinal rocks of the George River Group, which towards the top, interdigitate with volcanic rocks correlated with the Late Hadrynian volcanic rocks of the Fourchu Group. Spatially, gneiss and rocks of the George River Group lie to the northwest of a domain in which only volcanic rocks of the Fourchu Group crop out. The metamorphic grade increases from greenschist facies in the southeast to amphibolite facies in the northwest. Associated Late Hadrynian-Cambrian plutons are widespread in this subzone, where they are predominantly dioritoid and granitoid in composition. Tectonic interpretation of the Cape Breton Island subzone (Keppie, 1979a) suggests that it was part of an ensialic volcanic island arc. Polarity of the arc deduced from the spatial distribution of

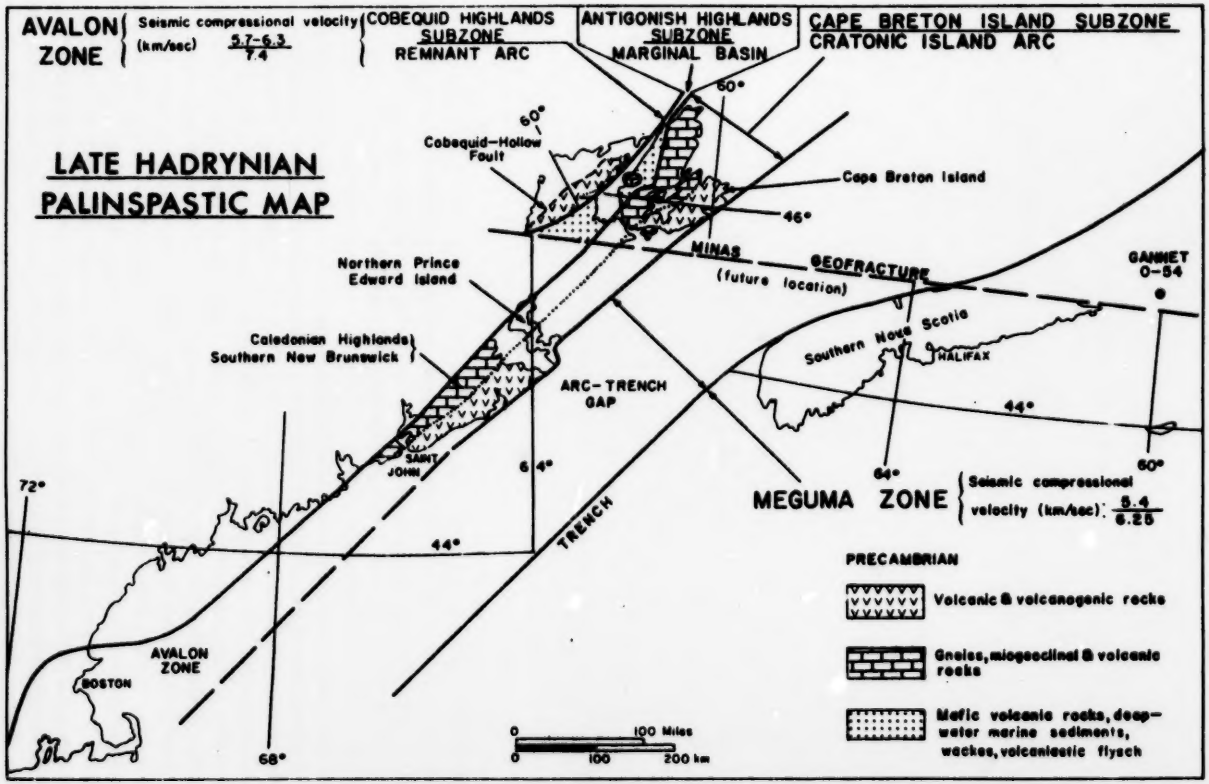

Figure 2. Late Hadrynian palinspastic map.

lithologies and metamorphism, and K_2O variations in the volcanic rocks suggest a northwesterly dipping palaeo-Benioff zone.

The Antigonish Highlands subzone is characterized by submarine mafic volcanic rocks, deep-water marine sediments, wackes and volcaniclastic flysch of the Georgeville Group (Keppie, 1978: Murphy *et al.*, 1979), which are inferred to be underlain by oceanic crust. Metamorphism is typically in the greenschist facies and plutonism is sporadic and mainly gabbroid in composition. The Antigonish Highlands subzone is inferred to represent part of a deformed marginal or back-arc basin (Keppie, 1979a).

The Cobequid Highlands subzone is characterized in the south by amphibolite facies gneisses, metavolcanic rocks, quartzite and schist of the Mt. Thom and Bass River Complexes, whereas in the north greenschist facies metavolcanic rocks with minor marble and siltstone of the Jeffers and Warwick Mountain Formations crop out (Donohoe and Wallace, 1978). Associated plutonism is limited to a few isolated dioritoid and granitoid plutons. The Precambrian rocks of the Cobequid Highlands are interpreted in terms of a remnant volcanic arc (Keppie, 1979a).

The Caledonian Highlands subzone (equivalent to Zone 5 or Ruitenberg *et al.*, 1977) is characterized by a southeastern belt of greenschist facies metavolcanics and volcanogenic rocks of the Coldbrook Group and a northwestern belt exposing gneiss, marble, quartzite and pelitic rocks of the Greenhead Group and metavolcanic rocks of the Coldbrook Group metamorphosed in the amphibolite and greenschist facies. Associated Late Hadrynian-Cambrian plutonism is mainly dioritoid and granitoid. The Caledonian Highlands subzone has been interpreted as either an intracratonic basin or an ensialic island arc (Rast *et al.*, 1976; Giles and Ruitenberg, 1977).

The Minas Geofracture Zone truncates the general northeast-southwest trend of all of the subzones in northern Nova Scotia and yet the Caledonian Highlands subzone may be traced northeastwards to the Magdalen Islands using gravity and magnetic anomalies (Haworth and Lefort, 1979) and southwestwards as far as the Boston area. This leads to speculations about the former southwestard continuation of the three subzones in northern Nova Scotia. A sinistral displacement on the Minas Geofracture is not likely because rocks of the Meguma Zone are not found elsewhere in the northern Appalachians. On the other hand, a dextral displacement along the Minas Geofracture implies that correlatives of the Cape Breton Island, Antigonish Highlands and Cobequid Highlands subzones may be found in the Avalon Zone of New Brunswick and New England. Comparisons suggest that the Cape Breton Island and Caledonian Highlands subzones are correlatives and share the following points in common: (a) a southeastern belt of volcanic and volcanogenic rocks metamorphosed in the greenschist facies, i.e., the Coldbrook and Fourchu Groups are equivalent; (b) a northwestern belt made up of diverse Precambrian lithologies including gneiss, quartzite, marble, pelites and metavolcanic rocks, metamorphosed in the amphibolite and greenschist facies, i.e., the Greenhead and George River Groups are correlatives; (c) widespread Late Hadrynian-Cambrian plutonism; (d) polyphase Late Hadrynian deformation; (e) tectonic interpretation of the volvanic rocks as part of the same ensialic island arc (Keppie, 1979a). Palinspastic restoration for Late Hadrynian times implies that a net dextral displacement of 370 km has taken place on the Minas Geofracture and dextral displacement of about 375 km on a major fault running

northeast-southwest through Chignecto Bay since Precambrian times. The Cobequid Highlands were arbitarily restored by moving them along the Cobequid-Hollow Fault to a position west of Cape Breton Island where the trend of the Precambrian structures in the Cobequid Highlands becomes parallel to the Late Precambrian trends in Cape Breton Island (Fig. 2). It should be noted that this Late Hadrynian reconstruction does not include any displacements parallel to the Appalachian trend. Thus, although the Meguma Zone lay on the southeast side of the Avalon Zone it may have lain northeast or southwest along strike of the position shown in Figure 2.

As a consequence of such reconstructions, several conclusions follow. Firstly, the east-west line near the Magdalen Islands terminating the northeastern continuation of the Caledonian Highlands subzone is the former westward continuation of the Minas Geofracture. Secondly, the palinspastic map predicts that the Meguma Zone must have continued to the north somewhere east of Cape Breton Island. On the Grand Banks, schist, greywacke, phyllite, quartzite and granite dated at 376 Ma using K-Ar were encountered at the bottom of the following wells: Gannet D-54, Bittern M-62, and Jaeger A-49 (Jansa and Wade, 1974). This granite body lies well to the east of the easternmost Devono-Carboniferous granite in the Burin Peninsula of Newfoundland suggesting it may be linked with those of the Meguma Zone. Although the age of the other rocks is unknown, it is possible that they could be Meguma Zone rocks. This perhaps finds support in the seismic velocities of 5.1 to 6.0 km/sec recorded in the vicinity of these wells which are more similar to those in the Meguma Zone than those in the Avalon Zone (Sheridan and Drake, 1968). These data provide some constraints on the Late Hadrynian position of the Meguma Zone. Finally, the Late Hadrynian palinspastic map suggests that a back-arc basin equivalent to the Antigonish Highlands subzone should lie on the western side of the Caledonian Highlands subzone, a proposal also suggested by Rast *et al.* (1976).

Cambrian-Early Ordovician

The Cambro-Ordovician rocks of southern New Brunswick and Nova Scotia fall into two general facies belts which coincide with the Avalon and Meguma Zones (Fig. 3). The Cambro-Ordovician rocks of southern Cape Breton Island (Weeks, 1954; Hutchinson, 1952; Smith, 1978) and very similar to those of the Saint John Group in southern New Brunswick (Alcock, 1938; Patel, 1973). Thus, both successions begin with nonmarine rocks followed by shallow marine Middle to Late Cambrian deposits overlain in turn by deeper water Late Cambrian-Early Ordovician black shales. In both areas, the transgression took place from south to north. The recently identified Cambrian rocks in the northern Antigonish Highlands (Murphy *et al.*, 1979) appear to fit into the same general facies belt. These Cambro-Ordovician rocks of the Avalon Zone are markedly different from the thick turbidites of the Meguma Group in the Meguma Zone. The only point of similarity is the occurrence of Tremadocian black shales in both zones.

Unfortunately, the Cambro-Ordovician rocks on the Avalon Zone occur in small isolated areas. Thus, these data cannot be used to unequivocally determine whether the Cambro-Ordovician belts were originally curved or straight and subsequently displaced by faults. The palinspastic map for the Cambro-Ordovician (Fig. 3) relies on data from the Silurian and Early Devonian which suggests that there were no position changes from the Late Hadrynian reconstruction (Fig. 2).

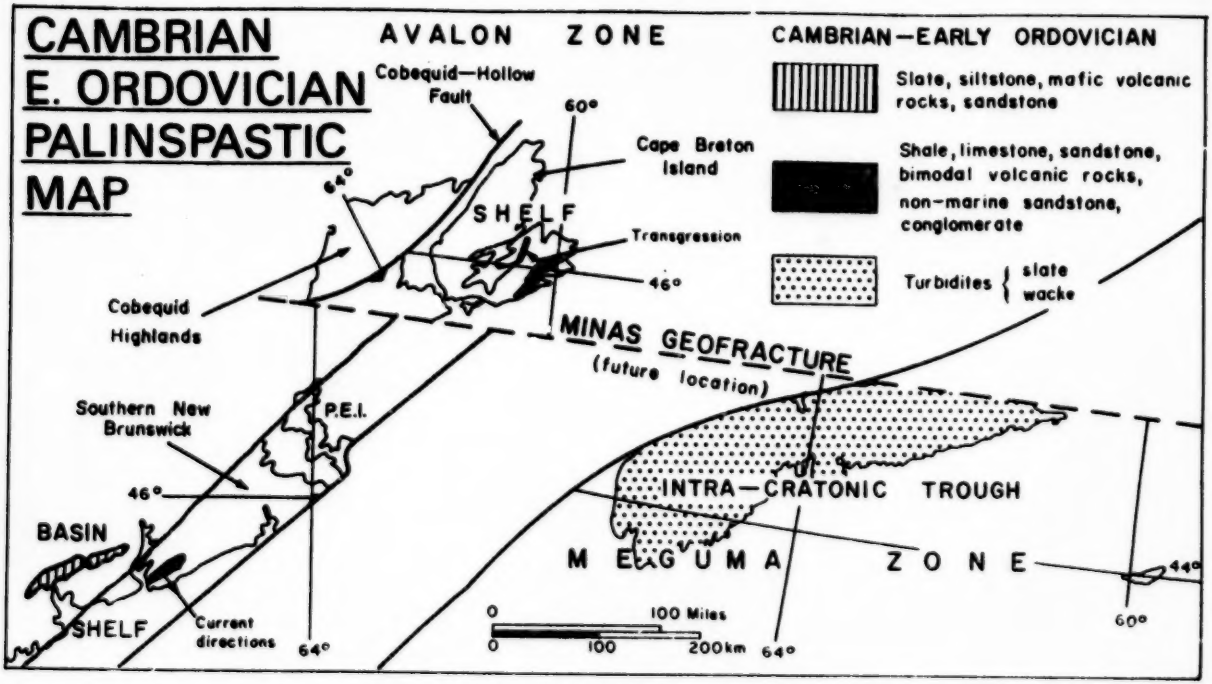

Figure 3. Cambrian-Early Ordovician palinspastic map.

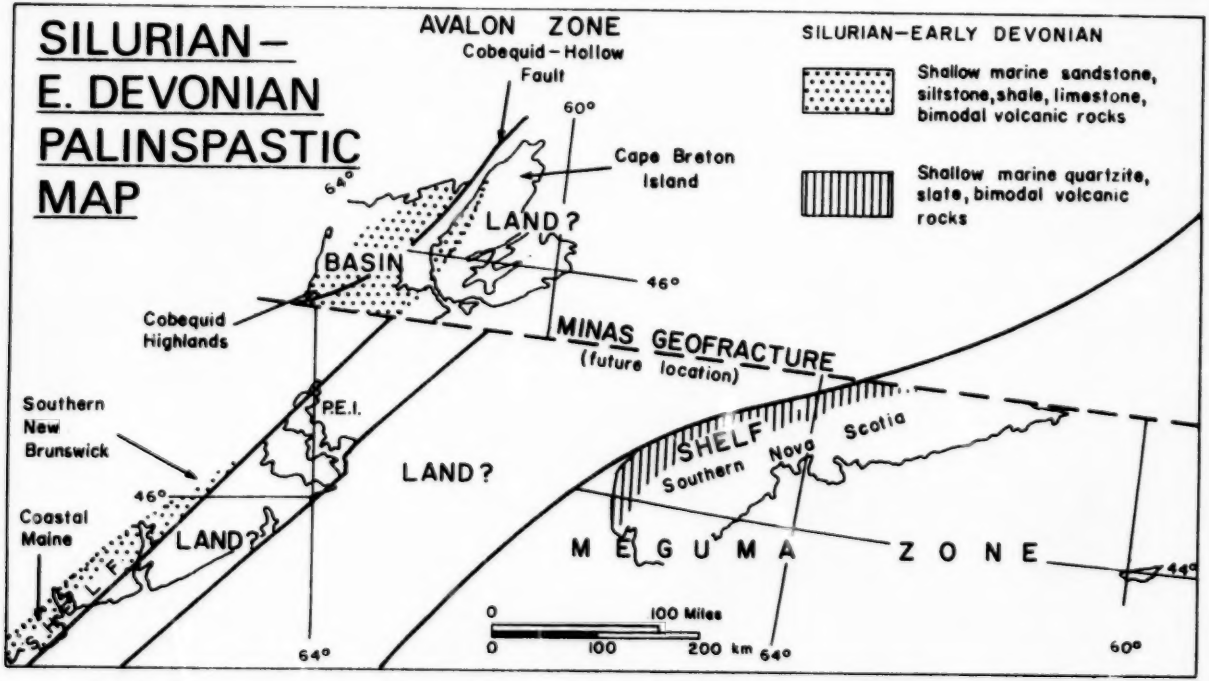

Figure 4. Silurian-Early Devonian palinspastic map.

Silurian – Early Devonian

The Silurian and Early Devonian rocks of southern New Brunswick and Nova Scotia may be divided into two broad facies belts separated by an inferred land area (Fig. 4). In the easternmost facies belt are the shallow marine Silurian-Early Devonian rocks along the northwestern side of the Meguma Zone. Sedimentological studies (Lane, 1975) indicate that the White Rock Formation changes from a shoreface facies on the northwestern side to a shelf mud facies to the southeast. The Early Devonian Torbrook Formation contains a fauna with Rhenish affinities (Boucot, 1960).

Silurian-Early Devonian rocks are absent in the Avalon Zone in southern New Brunswick and in Cape Breton Island except for an isolated occurrence near Mabou (Wait, 1959). This could be due to either nondeposition or deposition and subsequent erosion. However, the proximity of a shoreline on the northwestern side of the White Rock Formation and the northwesterly trending current directions in the latest Silurian-Early Devonian rocks in the Arisaig area (Boucot *et al.*, 1974) suggest the presence of an intervening land area.

In the second facies belt, from the Antigonish and Cobequid Highlands and along the Coastal Volcanic Belt in Maine to Newburyport near Boston, Silurian-Early Devonian rocks are relatively common. Except for the more common occurrence of volcanic rocks from Jones Creek to Newburyport, the sediments and brachiopod communities are remarkably similar (Boucot *et al.*, 1974; Watkins and Boucot, 1975; Cant, 1980), and indicate deep to shallow marine shelf and non-marine environments of deposition. It is significant that the Silurian-Early Devonian rocks in the southern Antigonish Highlands show none of the stratigraphic changes one would expect in approaching a large fault zone (Benson, 1967, 1974). This could be explained by assuming that the Minas Geofracture had no paleotopographic expression. A more palatable alternative is that the Minas Geofracture had not yet come into existence. Thus, the paleogeographic belts outlined above were originally continuous across the Minas Geofracture and have been displaced by subsequent faulting.

Middle Devonian

Coarse, molassic, mid-late Devonian rocks occur only to the north of the Minas Geofracture in Nova Scotia (Keppie, 1979b). In southern Nova Scotia, Early Carboniferous rocks rest unconformably upon Cambrian to Early Devonian rocks intruded by Devono-Carboniferous granitoid plutons. These granitoid plutons postdate the regional low pressure, high temperature regional metamorphism which in turn, post-dates the major Acadian folds (Keppie, 1977). Thus, the regional metamorphism is Middle-Late Devonian in age. Two areas of high temperature regional metamorphism occur around Shelburne and around Canso (Fig. 5). The Canso metamorphic high is bounded offshore to the west of the Fox I-22, Argo F-38, Crow F-52 and Wyandot E-53 wells, which bottomed in phyllite, sericite schist, chlorite-biotite metaquartzite and granite (Jansa and Wade, 1974). At present, this metamorphic high is truncated on the northern side by the Minas Geofracture (Keppie and Muecke, 1979). However, amphibolite facies metamorphism on Green Island, off the southern coast of Cape Breton Island, has recently been dated using $^{39}AR/^{40}$ Ar

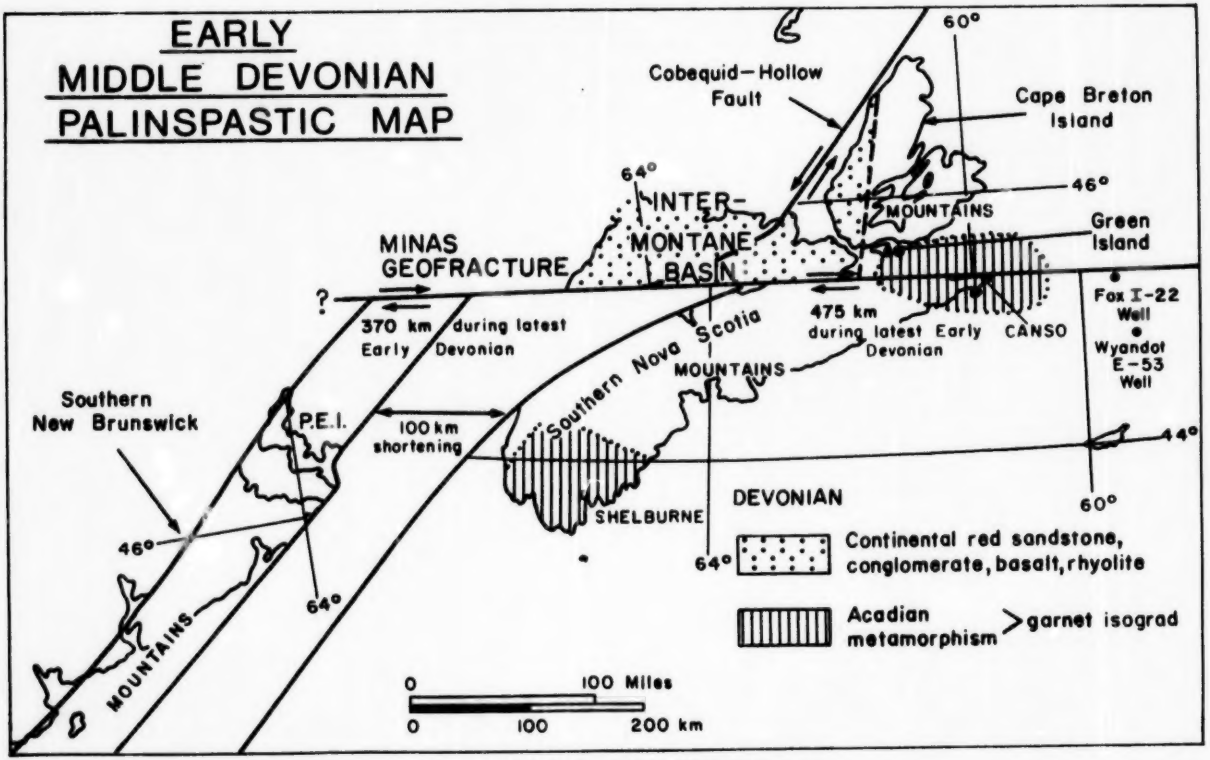

Figure 5. Middle Devonian palinspastic map.

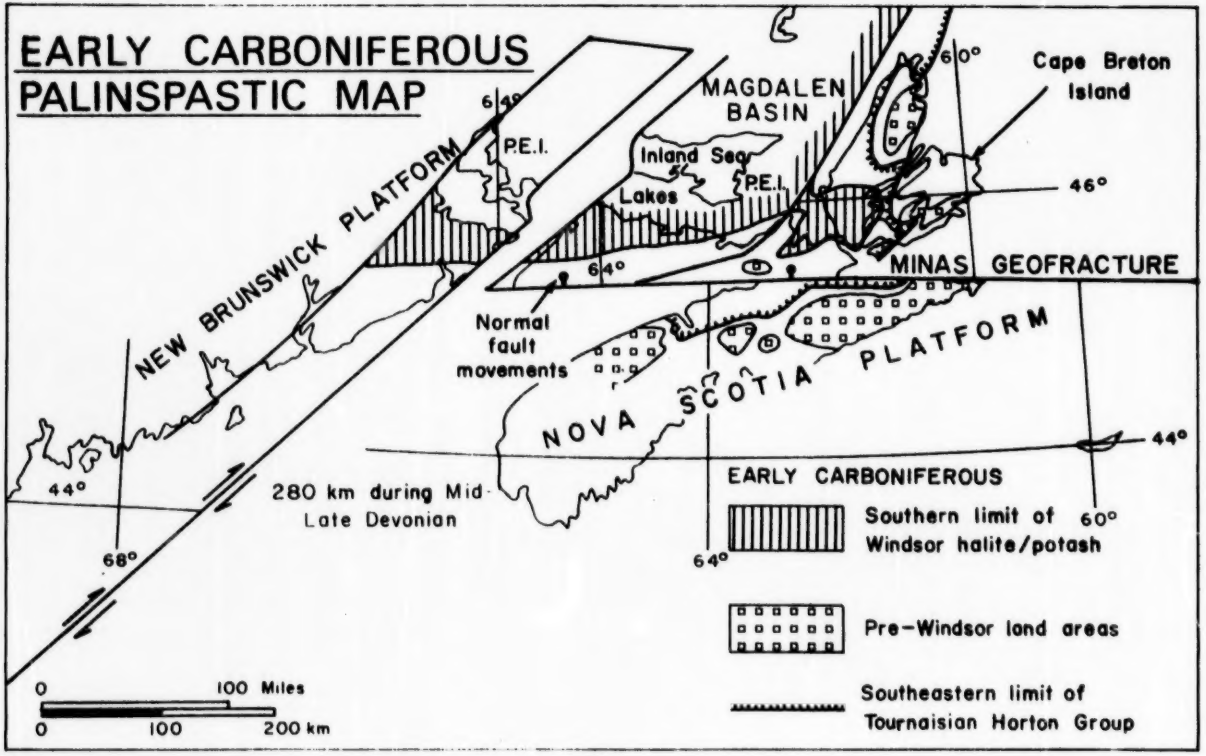

Figure 6. Early Carboniferous palinspastic map.

yielding 353 ± 2 Ma on biotite and 357 ± 4 Ma with a higher plateau at 391 ± 4 Ma on hornblende. The younger ages representing cooling ages whereas the older age probably represents the age of the regional metamorphic event, i.e., early Middle Devonian (Reynolds *et al.*, 1973; Reynolds and Muecke, 1978). The inferred offshore extent of this amphibolite facies metamorphism south of Cape Breton Island is shown in Figure 5. Palinspastic reconstructions across the Minas Geofracture for the Middle Devonian was accomplished by matching these metamorphic highs on either side of the Geofracture.

Carboniferous

Evaluation of data which may be used in palinspastic reconstructions across the Minas Geofracture provide no clear evidence. The Early Carboniferous age of most of the rocks south of the Minas Geofracture limits comparisons to rocks of this age. A line delimiting the southeastern limit of the Horton Group in Nova Scotia has a north-south to northeast-southwest trend except in the vicinity of the Minas Geofracture where it swings east-west (Fig. 6). This suggests that the Minas Geofracture had a paleotopographic expression during the deposition of the Horton Group. This was inherited from the Middle-Late Devonian at which time deposition was limited to the area north of the Minas Geofracture. Consequently, these data do not allow any firm palinspastic reconstructions to be based upon them (Webb, 1969). Also, facies data for the Horton Group are not defined clearly enough to be used.

Facies data for the Windsor Group on either side of the Minas Geofracture exhibit complex distribution patterns (Fig. 6) and do not allow any definite reconstructions to be made. Thus, in the absence of any clear data to the contrary, the Middle Devonian palinspastic reconstruction is applied to the Early Carboniferous. The generally quiescent tectonic conditions inferred during the deposition of the Horton and Windsor Groups lends some support to such a proposal. The position of southern New Brunswick relative to Nova Scotia (Fig. 6) assumes that the southern limit of halite and potash was originally a straight line across Chignecto Bay (P.S. Giles, pers. commun.).

Permo-Triassic

There appears to be no available data relevant to palinspastic reconstructions across the Minas Geofracture. The palinspastic map for Permian times (Fig. 7) is based upon tectonic criteria discussed below.

DISCUSSION

The palinspastic maps prepared for various times from Late Hadrynian to Permian times for southern New Brunswick and Nova Scotia provide some constraints on tectonic movements:

(i) The Late Hadrynian palinspastic map (Fig. 2) implies that the Caledonian Highlands was formerly a southwesterly continuation of Cape Breton Island. Data from the Cambro-Ordovician and especially the Silurian-Early Devonian suggest that this reconstruction persisted throughout the Early Paleozoic and into the Early Devonian. Thus, the Minas Geofracture did not exist until after the Early Devonian.

(ii) During the initial compressive phase of the Acadian Orogeny, the Minas Geofracture saw 370 km dextral movement between southern New Brunswick and Cape Breton Island and 475 km dextral movement of southern Nova Scotia (Figs. 2 to 5). The difference is inferred to have been taken up in folding and compressive strain in the area between southern Nova Scotia and the Caledonian Highlands subzone. These movements took place between early Emsian time (the age of the youngest rocks deformed by the compressive phase of the Acadian Orogeny) and the regional metamorphism at 391 ± 4 Ma, i.e., about 10 Ma. This gives a movement rate of 3.7 to 4.75 cm per year.

(iii) Negative evidence suggests that not much relative movement took place on the Minas Geofracture between late Middle Devonian and Early Carboniferous times. However, about 280 km dextral movement took place upon a fault or faults parallel to Chignecto Bay. It is inferred that as a consequence of these dextral movements the Magdalen Basin formed as a pull-apart basin where the Appalachians swing east-west through the Gulf of St. Lawrence. The Middle and Late Devonian volcanism is inferred to indicate the time during which rifting was active (Keppie and Dostal, 1980). Continued subsidence of the Magdalen Basin during the Carboniferous is inferred to be largely the result of isostatic adjustment due to sedimentary loading.

(iv) In a number of recent papers, various authors (Kent and Opdyke, 1978; Irving, 1979; Van der Voo *et al.*, 1979) have inferred from limited paleomagnetic data that the eastern part of New England and the Maritime Provinces has moved about

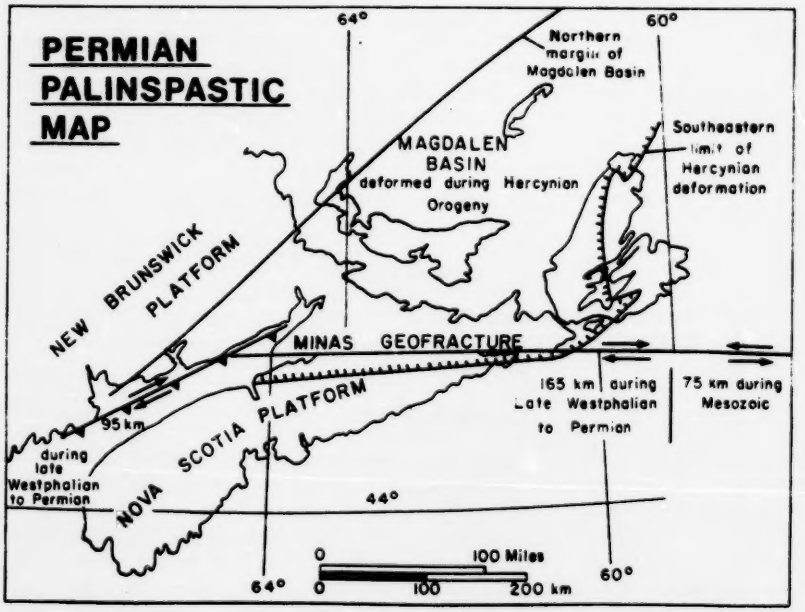

Figure 7. Permian palinspastic map.

1500 to 2000 km northeastwards relative to the rest of North America during the Early Carboniferous. They infer that these movements took place on a sinistral fault zone extending from New York City to Chaleur Bay. If movements of such a magnitude had occurred, intense compressive deformation would have occurred in the Carboniferous Magdalen Basin where the Appalachians swing through an east-west trending Gulf of St. Lawrence segment. Although there is some minor deformation of sedimentary rocks in the Magdalen Basin, it is mainly evident near its margins and is virtually absent in the centre. Thus, such movements are not in agreement with the geological data. Re-examination of the paleomagnetic data reveals that the sampling sites in New England and the Maritimes lie close to the coast of the Bay of Fundy and the Gulf of Maine. It is possible to accommodate major sinistral movements on major faults lying further south such as the Lubec-Belleisle Fault and Norembega-Fredericton Fault. These faults may be connected with the Cabot Fault in Newfoundland with only minor deflection in the Gulf of St. Lawrence, and it is possible that such deflection as there is was produced during the Late Carboniferous-Permian Hercynian Orogeny. If these faults were approximately straight through the Gulf of St. Lawrence and eastern New England, and the southern Maritimes and eastern Newfoundland moved as an internally coherent block, then major sinistral movement could be accommodated without producing intense deformation of the Magdalen Basin. Correlation of the halite-potash facies boundary in the Visean Windsor Group between southern New Brunswick and Nova Scotia (Fig. 6) would support such internal coherency, unless these major sinistral movements were completed by Visean times. More paleomagnetic data would indubitably provide better constraints on the time and location of these large sinistral movements.

(v) The Magdalen Basin was deformed between Early Westphalian and Late Triassic times by movements associated with the Hercynian Orogeny. During this time about 165 km dextral movement is inferred to have taken place on the Minas Geofracture. This figure is controlled by considering the magnitude of movements that have taken place during the Mesozoic to open the Bay of Fundy Rift (Keppie, 1977). These movements are consistent with the calc-alkaline nature of the Late Carboniferous volcanism at Saint John, New Brunswick, which implies the closing of a small ocean basin between Nova Scotia and New Brunswick (Strong *et al.*, 1979). Contemporaneously, thrusting and about 95 km dextral displacement took place along northeast-southwest faults along the coast of southern New Brunswick. Deformation of the sediments in the Magdalen Basin at this time was most intense along its margins (Keppie, 1979c)

(vi) Rifting associated with the opening of the Bay of Fundy during Triassic, Jurassic and Cretaceous times was of limited extent because there appears to be no axial dyke. These rift movements are translated into sinistral movements on the Minas Geofracture and are inferred to be in the order of 75 km.

These data show that the Minas Geofracture has a complex history of repeated movement since it originated during the Devonian Acadian Orogeny. It is interesting to note that the deformation during both the Acadian and Hercynian Orogenies consists of folding and dextral movement upon the Minas Geofracture and the fault parallel to Chignecto Bay. In each case, this is interpreted in terms of dextral transpression caused by oblique collision. Thus, the initial collision was followed by

dextral transcurrent faulting parallel to the strike of the orogen. The 1500 to 2000 km northward movement of the Avalon and Meguma Zones during the interval between the Acadian and Hercynian Orogenies is analogous to the rapid motion of microplates during the dying stages of the Tethys Ocean.

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